PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
B22D 19/14, 1/00 // 17/02, C22C 1/10

A1

(11) International Publication Number: WO 96/24453

(43) International Publication Date: 15 August 1996 (15.08.96)

(21) International Application Number: PCT/AU96/00060

(22) International Filing Date: 9 February 1996 (09.02.96)

(30) Priority Data:
PN 1071 10 February 1995 (10.02.95) AU

(71)(72) Applicant and Inventor: WITHERS, Graham, Rex [AU/AU]; 1297 Nepean Highway, Cheltenham, VIC 3192 (AU).

(74) Agent: WATERMARK PATENT & TRADEMARK ATTORNEYS; 2nd floor, 290 Burwood Road, Hawthorn, VIC 3122 (AU).

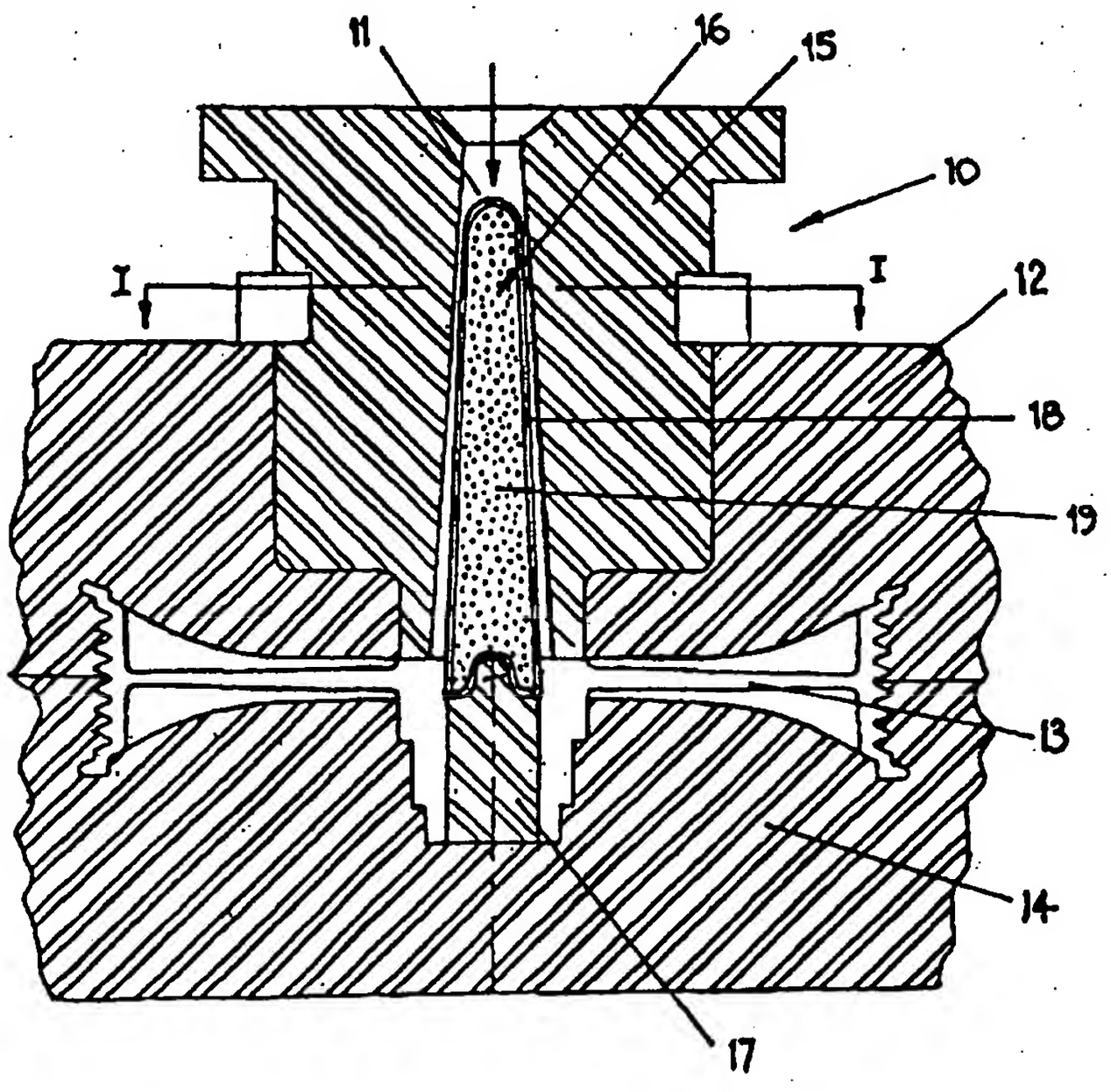
(81) Designated States: AU, CA, CN, JP, KR, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: FORMING METAL MATRIX COMPOSITE WITH PARTICULATE FILLER

(57) Abstract

An apparatus (10) and a method are provided for moulding or die casting a metal matrix composite product with a dispertion of particulate filler material. A cartridge (16) is inserted into the inlet passage (11) to the mould or die cavity (13), the cartridge (16) having at least one outer section (18) rupturable by molten metal flow and containing particulate filler material (19). The arrangement is such that when molten metal is injected through the inlet passage (11), it ruptures the cartridge (16) and carries the particulate filler material (19) into the mould or die cavity (13) while at the same time dispersing the filler material (19) throughout the molten material.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia
AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgystan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam

FORMING METAL MATRIX COMPOSITE WITH PARTICULATE FILLER

The present invention relates primarily to a novel method of forming and apparatus for forming metal matrix products, however, the method and apparatus may also be useful in moulding products made from any material in which it is desired to disperse a particulate or fibre filler material. This invention will be particularly useful in producing products disclosed in Patent Nos. 83399/87 (GENI) and 61450/90 (GENII).

In the prior art there is disclosure of methods and apparatus for forming metal products using, for example aluminium or its alloys, magnesium or its alloys, tin or its alloys and zinc or its alloys, in which a particulate filler material is dispersed such as fly ash or other ceramic particles. There are certain advantages in using such fillers in that it may provide lighter and at least as strong end products that are cheaper because the filler is not as expensive as the metal. Other advantages include the ability to adjust or improve ductility, wear resistance, hardness, thermal expansion and other similar properties. It is, however, desirable to achieve a simple and inexpensive method of producing such products such that any savings resulting from the materials used are not wasted by the manufacturing methods and the costs of the apparatus required to form the product.

Several difficulties exist in relation to mixing particulate material into a liquid matrix (such as a metal matrix) prior to being introduced in a mould or die cavity. These include that, depending on the materials involved, the particulate material might tend to float or sink in the matrix material so that widely different dispersion levels can result in the product ultimately formed.

This can occur if the particulate material is mixed into the liquid matrix material well before introduction into the mould or die. This may be partly resolved by continually mixing the particulate material and the matrix material, however, this adds a further cost and difficulty and moreover, stratification can still result as the material is transferred from the mixing zone to the die or mould. The additive materials may also be destroyed or damaged as a result of mechanical or other types of mixing apparatus in a melting pot. The additives

may also become scorched under super heated conditions that the liquid metal is kept, thus resulting in intermetallic phases.

A still further difficulty is that it is difficult to mix particulate material that might be reactive to some extent with the liquid matrix material as extensive mixing times provide for the possibility of deleterious reactions between the materials.

The objective therefore is to provide a relatively low cost method and apparatus for forming products by moulding techniques comprised of a particulate material dispersed in a matrix material with the particulate material having satisfactory dispersion levels for the product being formed.

Accordingly, the present invention provides in a first aspect, a method of forming a composite product comprising heating a metal matrix material to its liquid state, introducing said liquid metal matrix material to a mould or die cavity while still in its liquid state, and introducing a volume of particulate filler material into said liquid matrix material either at or immediately prior to an entry point of said liquid metal matrix material into said mould or die cavity. Preferably this introduction point of the particulate material occurs in the mould or die. In accordance with this aspect the present invention also proposes apparatus for forming a composite product comprising a mould or die including a mould or die cavity, means for receiving and introducing a molten metal matrix material into said mould or die cavity, and means for introducing a volume of particulate material into said molten metal matrix material either at or immediately prior to said molten metal matrix material entering said mould or die cavity. It has been surprisingly found that introducing the particulate material as aforesaid provides adequate distribution of the particulate material in the product being formed.

In accordance with a preferred aspect of the present invention there is provided a method of forming a composite product comprising the steps of providing:

a mould or die with a mould or die cavity;

locating a volume of particulate material in a path for the flow of liquid matrix material into said die or mould cavity, said particulate material being located in an outer sheath capable of being at least partially ruptured by liquid

matrix material flowing into said die or mould cavity; and

heating a matrix material to its liquid state and arranging same to flow past said volume of particulate material whereby said particulate material is carried with and dispersed through said liquid matrix material within said die or mould cavity. In accordance with this aspect, the present invention also provides apparatus comprising a mould or die having a mould or die cavity, a liquid flow path for liquid matrix material leading into said mould or die cavity, and means located in said liquid flow path either at or immediately before an entry point into the mould or die cavity to support a volume of particulate located in an outer sheath, said outer sheath being adapted for rupture upon said liquid matrix material passing along said liquid flow path. Conveniently the sheath material may be a metal foil. In the case of moulding a metal matrix material such as aluminium or its alloys or magnesium or its alloys, the metal foil of sheath material might appropriately be either or both an aluminium (or its alloys) or magnesium (or its alloys) foil. In such a case the foil material might be heated by the incoming liquid matrix material beyond its liquid state and the sheath material might simply form part of the liquid matrix material entering the mould or die cavity. In any event in such circumstances, the sheath material should not be made of a material that will adversely react with the liquid matrix material.

In a still further aspect, the present invention also provides a cartridge for location in an inlet flow passage of a die or mould, said cartridge having an outer wall of metal configured to be positioned in said inlet flow passage and retaining particulate filler material within an inner space thereof.

In a still further aspect, the present invention also provides a method of die casting metals with a dispersion of particulate filler material, said metal injected as molten metal into a die cavity of a die, the injection of the molten metal into said die cavity being through an inlet runner leading into the die cavity, said method comprising: inserting into said runner a cartridge containing a predetermined volume of particulate filler material to be dispersed in a metal casting, said cartridge being sealed by at least one section formed by a metal foil layer so as to retain the filler material within the cartridge; injecting molten metal into the cavity through said cartridge, thereby rupturing the foil layer

carrying the filler material into the cavity while intermixing the particulate filler material with said molten metal; and allowing said molten metal to solidify in the die cavity before removing same.

Throughout this specification, particulate material is referred to. It should be understood that this includes but is not limited to, fly ash or other ceramic particles (either spherical or not) and fibres including steel or other metal fibres and glass fibres. Obviously the material of the particulate material will depend upon the nature of the matrix material being used therewith and the product being formed.

Further, when the matrix material is a metal, the sheathing material is either made from the same metal or at least a metal compatible with the matrix metal as the sheathing material is at least in part incorporated in the end product formed.

One preferred arrangement will hereinafter be described with reference to the accompanying drawings, in which :-

Figure 1 is a partial cross-sectional view of the die chamber of a hot chamber die casting device according to the present invention;

Figure 2 is a partial cross-sectional view similar to Figure 1 showing an alternative preferred embodiment;

Figure 3 is a partial cross-sectional view similar to Figure 1 showing a still further preferred embodiment.

Figures 4, 5 and 6 are respective cross-sectional views taken on line I-I of Figures 1 to 3 showing different possible arrangements within the inlet molten metal delivery path of the hot chamber die casting device.

The annexed drawings illustrate various features of a hot chamber casting device 10. Molten metal can be delivered by any known method or apparatus to the inlet path 11 of the casting device 10 which is formed in a fixed die part 12. A die cavity 13 is formed between the fixed die part 12 and a movable die part 14 with the inlet path 11 leading into the die cavity 13. In the drawings, the die cavity 13 is shaped so as to enable a power steering pump pulley for a motor vehicle to be die cast but it will be apparent that many other shapes can be die cast according to the principles of the present invention. The

fixed part die part 12 includes a sprue bushing 15 through which the inlet passage or runner 11 is formed. Prior to a casting operation, a cartridge 16 is positioned within the inlet runner 11 as illustrated in Figures 1, 2 and 3 with the structure of the cartridge 16 being as described hereinafter. Conveniently, the cartridge 16 may be mounted at least partially on a sprue post 17 or any other means might be utilised to locate the cartridge 16 as desired in the inlet runner 11. The cartridge 16 comprises an outer structural sheath 18 and a predetermined quantity of filler material particles 19 depending on the desired quantity of such material in the finished product. The filler material particles are conveniently microspheres such as fly-ash but many other forms of filler material could also be utilised.

During a die casting operation, the cartridge 16 is first positioned as desired in the inlet runner 11 and the die parts 12 and 14 are closed and pressed against one another. Thereafter, molten metal (conveniently magnesium, aluminium or alloys of magnesium and aluminium) is introduced into the die cavity 13 under high pressure through the inlet runner 11. At least part of the sheath material 18 is ruptured and the filler material is carried into the die cavity 13 with the molten metal while being dispersed throughout the molten metal. The introduction of the molten metal into the die cavity 13 occurs very rapidly (often in less than a second) which enables the filler material particles to disperse well throughout the molten metal. Further, it will be apparent that in the illustrated embodiments, the cartridge 16 is located right at the introduction point to the mould cavity such that there is insufficient time for the filler material particles 19 to adversely react with the molten metal.

Conveniently, the sheath material 18 may be a metal foil such as aluminium foil, magnesium foil or a combination of both as illustrated in Figure 1 with the whole outer wall of the cartridge being formed by the foil. In other preferred arrangements as shown in Figures 2 and 3, the sheath may be preformed as a thin metal conical container 20 with the metal being either aluminium or magnesium or alloys of these metals. The container 20 is then capped off at either end 21 or 22 by a thin metal foil (either aluminium, magnesium or alloys of same). The sheath 18 is preferably filled with the

desired particulate material prior to being positioned in the inlet runner 11. The cartridge 16 thus formed by either of the above described methods may contact the wall of the inlet runner 11 or may have a clearance fit within the runner as shown in the drawings. The configuration of the cartridge 16 of particulate material may vary depending on the nature of the product being produced and the desired dispersion of the particulate material. In the case of producing a pulley wheel as illustrated, it may be desired to achieve a reasonably high level of filler material 19 (fly-ash or microspheres) in the region of the outer peripheral pulley grooves. In this situation the package of particulate material may have a relatively small distance or no distance between it and the wall 23 of the inlet runner 11 so that a reasonably high proportion of the filler material 19 is pushed in front of the molten metal towards the extremity of the mould cavity. If this is not a requirement and a more even distribution of particulate material is required, then a greater distance between the sheath and the sprue wall might be provided. Further, in some situations, it may be desirable to give the sheath a non-circular cross-section (eg. polygonal or wave as shown, for example in Fig. 6) so that the space between the wall 23 of the inlet runner 11 and the sheath 18 is greater at different circumferential locations. It may also be desirable, in some situations, to vary the thickness of the sheath material 19, eg. thicker near the entry to the die or mould cavity and thinner at its free end to assist with rupture of the sheath 18 and achieving a desired dispersion of the particulate material 19.

In a further embodiment, it is proposed to automate introduction of cartridges 16 of the above described format into the inlet runner 11 of the die casting apparatus. This might be achieved by placing the cartridges 16 in a feed magazine (not shown) so that they are positioned sequentially, as illustrated in the drawings, each time the die is opened to allow removal of the cast end product. Thus, when the die is closed, it will immediately be ready for a new die casting operation. In a still further arrangement, it is possible to locate the particulate filler material (fly-ash or the like) in individual cartridges or pockets formed on an elongated chain of such cartridges or pockets. Such a chain could be formed by metallic foil (typically magnesium, aluminium or their alloys) utilising the foil as the carrier for the chain. Alternatively, the foil

cartridges or pockets containing the fly-ash or other particulate filler material could be sequentially mounted on a web of some other material to deliver the cartridges to the die casting machine. In such a configuration, a single or possibly multiple cartridges or pockets could be separated from the carrier as the die closes so as to leave the or a selected number of such cartridges or pockets in the inlet runner 11 prior to injection of molten metal.

Arrangements as described above have been found to work satisfactorily in practice. It should however be appreciated that high pressure die casting techniques are not the only possible techniques that could be used. It is believed the methods described above might be used in hot or cold chamber die casting, squeeze casting, injection moulding, semi-solid forming, gravity/sand/centrifugal casting and continuous casting. When high injection pressures are not used in the moulding process, it is possible to simply inject through a nozzle the desired particulate material into the liquid matrix introduction path. If turbulent conditions are not created by the liquid matrix introduction path itself then it might be desirable to provide specific turbulence enhancing devices in the introduction path to promote mixing of the particulate material with the matrix material.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of forming a product comprising heating a metal matrix material to its liquid state, introducing said liquid metal matrix material to a mould or die cavity while still in its liquid state, and introducing a volume of particulate filler material into said liquid matrix material either at or immediately prior to an entry point of said liquid metal matrix material into said mould or die cavity.

2. A method of forming a composite product comprising the steps of providing:

a mould or die with a mould or die cavity;

locating a volume of particulate material in a path for the flow of liquid matrix material into said die or mould cavity, said particulate material being located in an outer sheath capable of being at least partially ruptured by liquid matrix material flowing into said die or mould cavity; and

heating a matrix material to its liquid state and arranging same to flow past said volume of particulate material whereby said particulate material is carried with and dispersed through said liquid matrix material within said die or mould cavity.

3. A method according to Claim 2, wherein said matrix material is a metal.

4. A method according to Claim 3, wherein said metal is aluminium, magnesium, zinc, tin or alloys of aluminium, magnesium, zinc or tin.

5. A method according to Claim 3 or Claim 4, wherein said particulate materials are microspheres.

6. A method according to Claim 5, wherein the microspheres are ceramic microspheres.

7. A method according to Claim 5, wherein the microspheres are fly-ash.

8. A method according to any one of Claims 3 to 7, wherein the sheath material is a metal.

9. A method according to Claim 8, wherein the metal is a metal foil.

10. A method according to Claim 8, wherein the sheath material is formed as a container with container walls and an open mouth region closed by a metal foil layer.

11. A method according to Claim 10, wherein the container has opposed open ends each of which is closed by a metal foil layer.

12. A method according to any one of Claims 8 to 11, wherein the metal of the sheath material is compatible with the metal forming the matrix material.

13. A method according to Claim 12, wherein the metal of the sheath material is aluminium, magnesium, tin, zinc or alloys of aluminium, magnesium, tin or zinc.

14. Apparatus for forming a composite product comprising a mould or die including a mould or die cavity, means for receiving and introducing a molten metal matrix material into said mould or die cavity, and means for introducing a volume of particulate material into said molten metal matrix material either at or immediately prior to said molten metal matrix material entering said mould or die cavity.

15. Apparatus comprising a mould or die cavity, a liquid flow path for liquid matrix material leading into said mould or die cavity, and means located in said liquid flow path either at or immediately before an entry point into the mould or die cavity to support a volume of particulate located in an outer sheath, said outer sheath being adapted for rupture upon said liquid matrix material passing along said liquid flow path.

16. Apparatus according to Claim 15, wherein said sheath material is a metal.

17. Apparatus according to Claim 16, wherein the metal is a metal foil.

18. Apparatus according to Claim 16, wherein the sheath material is formed as a container with container walls and an open mouth region closed by a metal foil layer.

19. Apparatus according to Claim 18, wherein the container has opposed open ends each of which is closed by a metal foil layer.

20. A cartridge for location in an inlet flow passage of a die or mould, said cartridge having an outer wall of metal configured to be positioned in said inlet flow passage and retaining particulate filler material within an inner space thereof.

21. A cartridge according to Claim 20, wherein the outer wall includes at least one section which is capable of rupture by molten metal flowing through said inlet passage.

22. A cartridge according to Claim 21, wherein the or each said section is formed by a metal foil.

23. A cartridge according to any one of Claims 20 to 22, wherein the outer wall is formed by a metal foil.

24. A cartridge according to any one of Claims 20 to 23, wherein the filler material is fly-ash.

25. A cartridge according to any one of Claims 20 to 24, wherein the metal of said outer wall is magnesium, aluminium, zinc, tin or alloys of magnesium, aluminium, zinc or tin.

26. A method of die-casting metals with a dispersion of particulate filler material, said metal injected as molten metal into a die cavity of a die, the injection of the molten metal into said die cavity being through an inlet runner leading into the die cavity, said method comprising: inserting into said runner a cartridge containing a predetermined volume of particulate filler material to be dispersed in a metal casting, said cartridge being sealed by at least one section formed by a metal foil layer so as to retain the filler material within the cartridge; injecting molten metal into the cavity through said cartridge, thereby rupturing the foil layer carrying the filler material into the cavity while intermixing the particulate filler material with said molten metal; and allowing said molten metal to solidify in the die cavity before removing same.

27. A method according to Claim 26, wherein the cartridge is made of a metal compatible with the molten metal injected into the die cavity.

28. A method according to Claim 27, wherein the cartridge is made of the same metal as the molten metal injected into the die cavity.

29. A method according to any one of Claims 26 to 28, wherein the molten metal is an aluminium or magnesium alloy.

30. A method according to any one of Claims 26 to 29, wherein the filler material is fly-ash.

Fig 1.

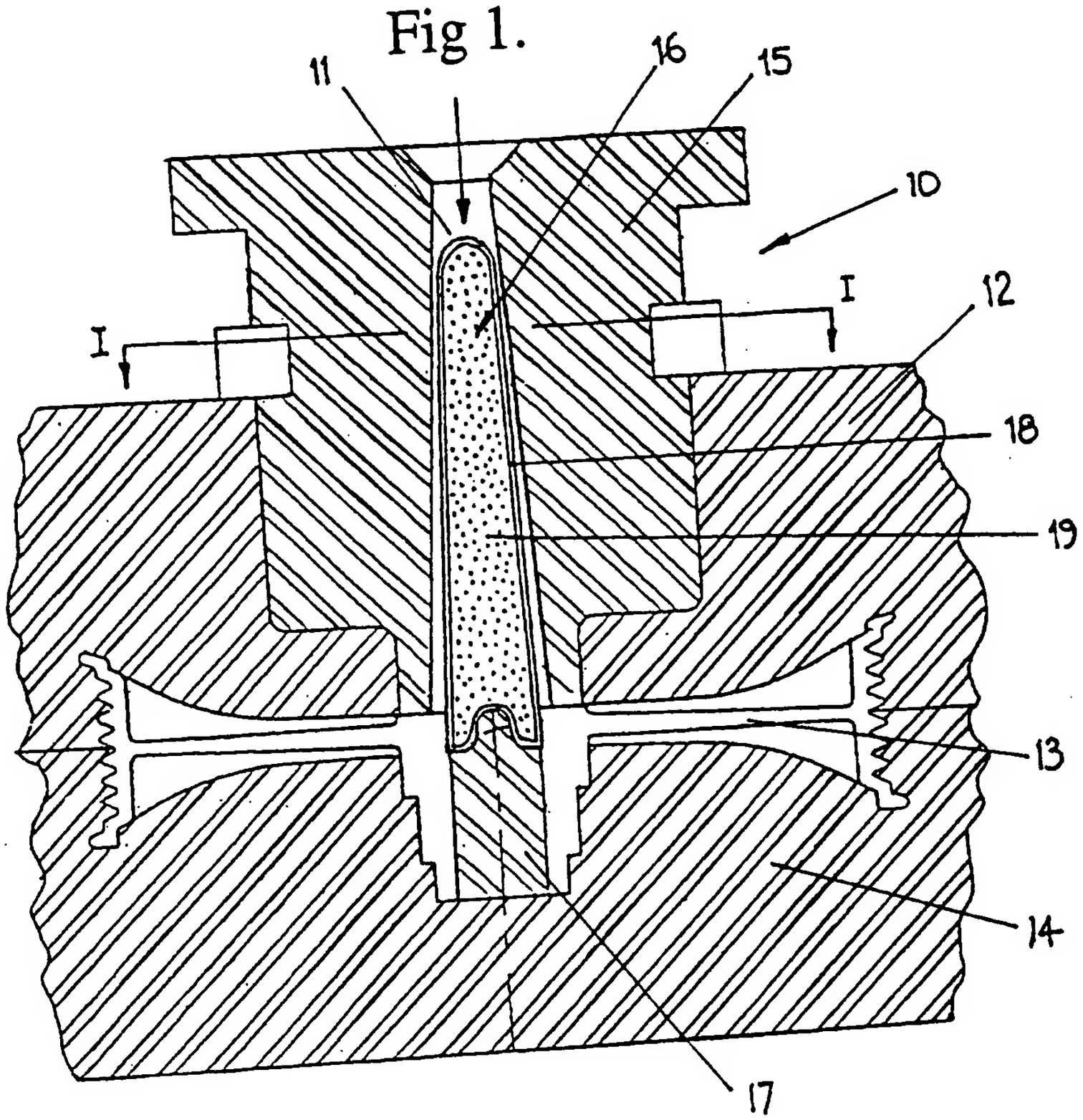


Fig 2.

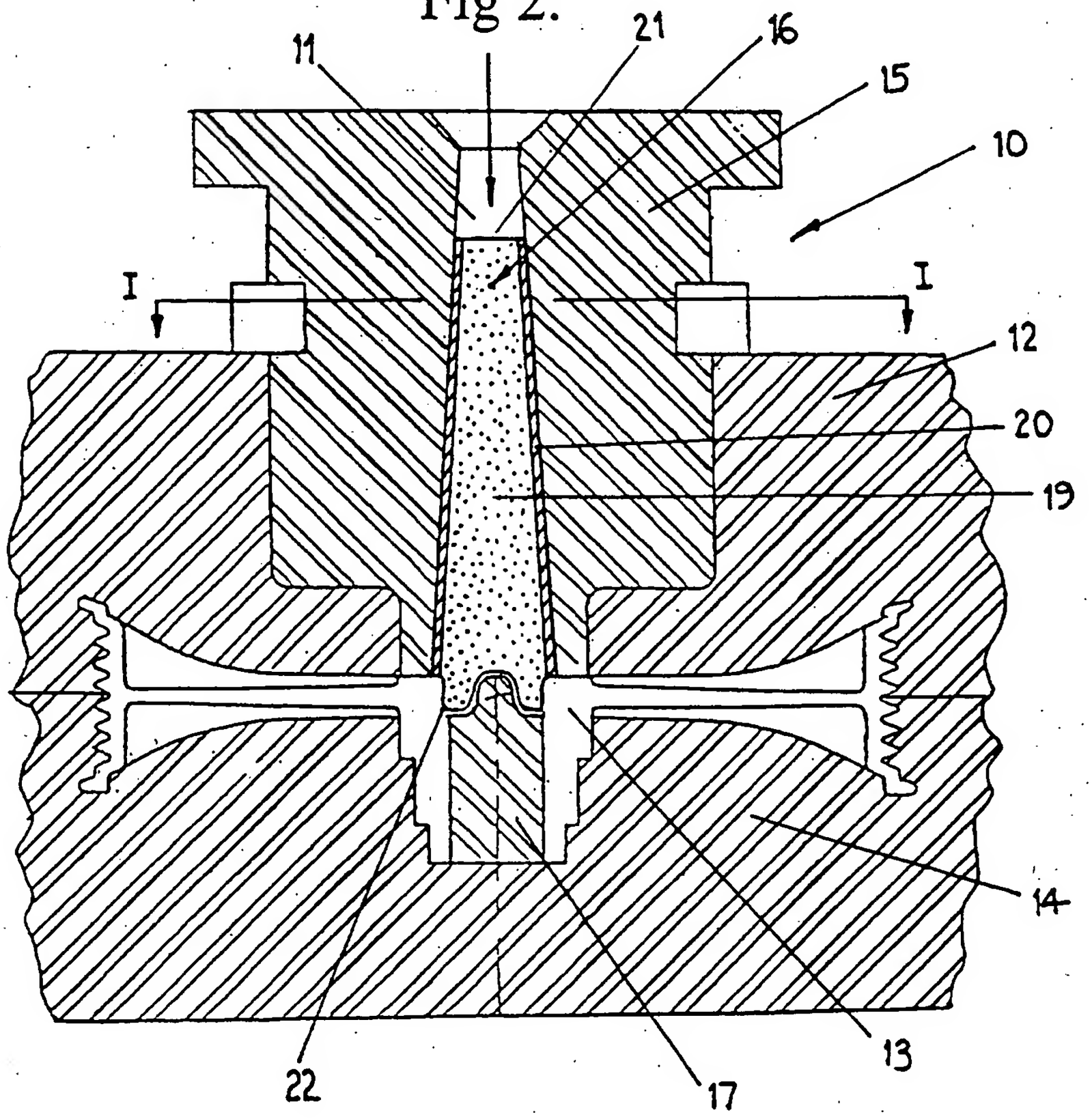


Fig 3.

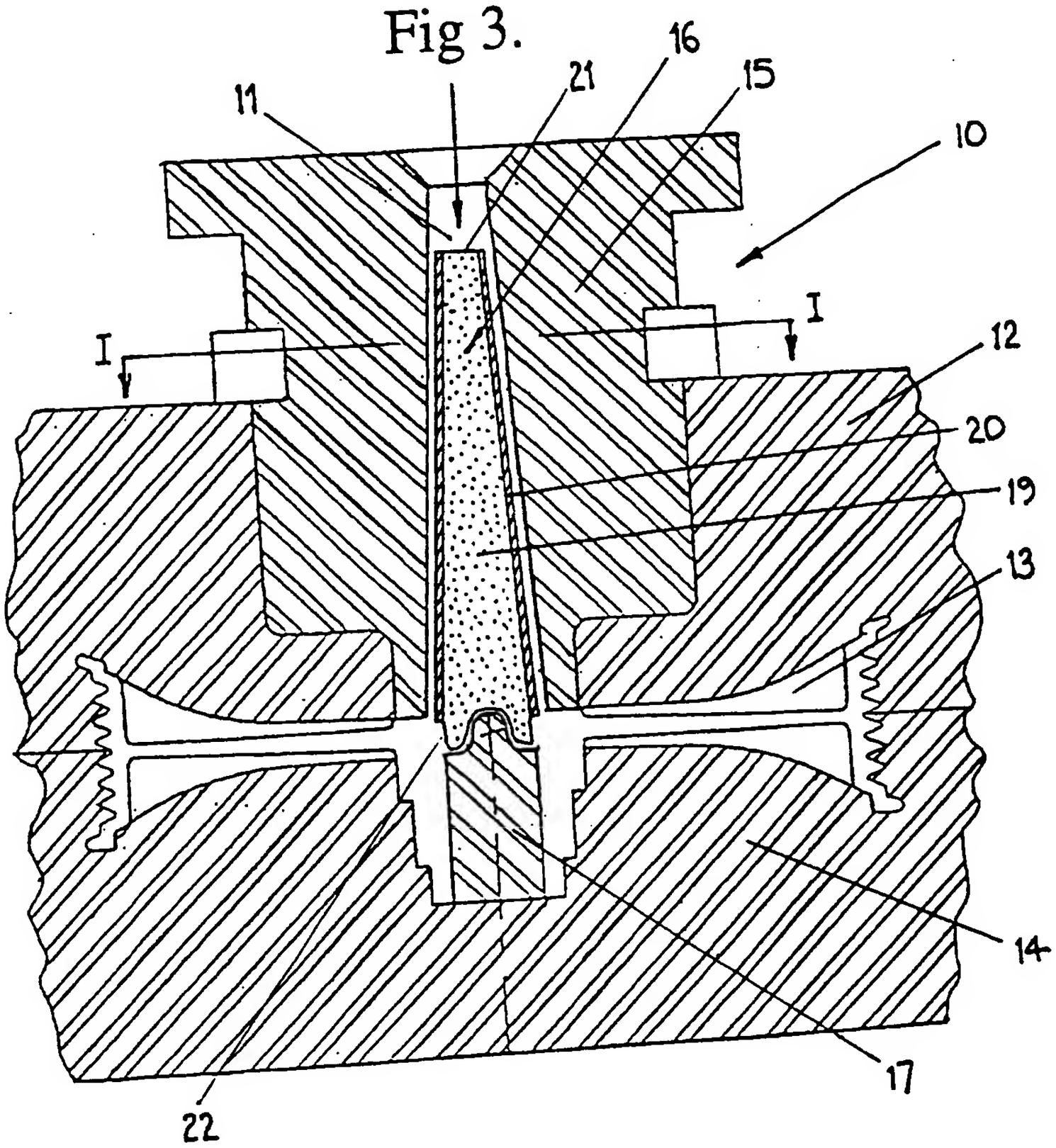


Fig 4.

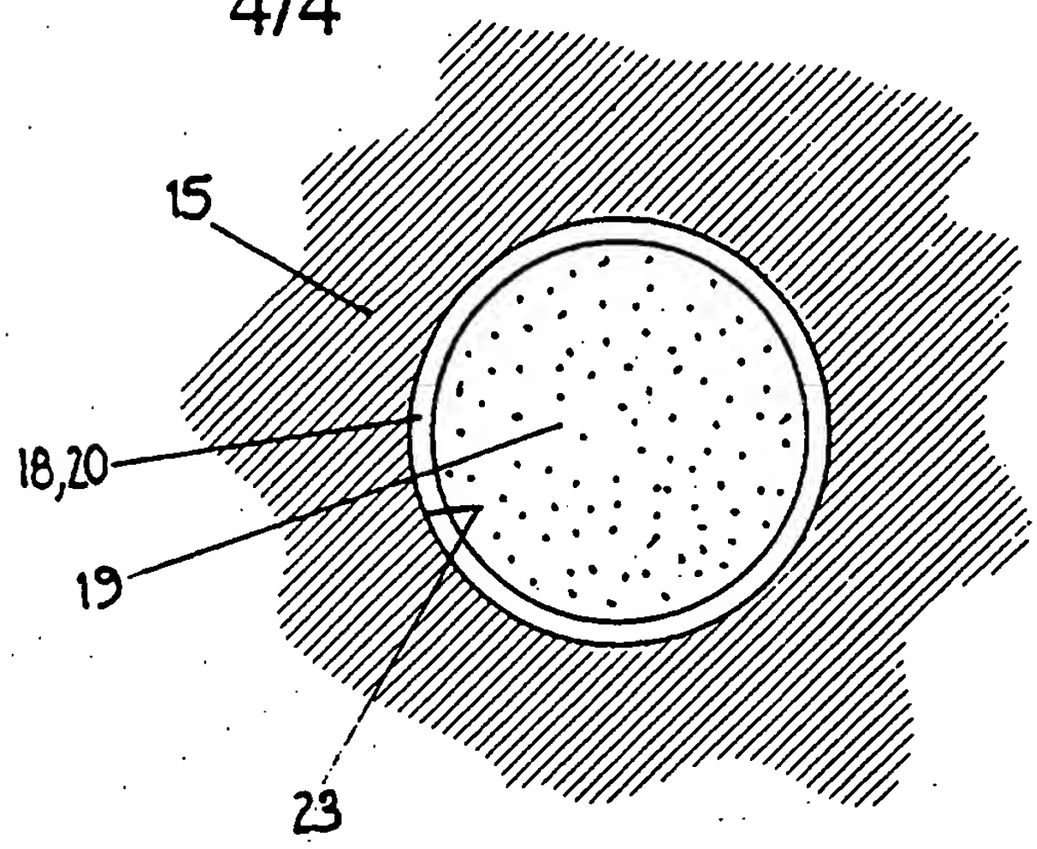


Fig 5.

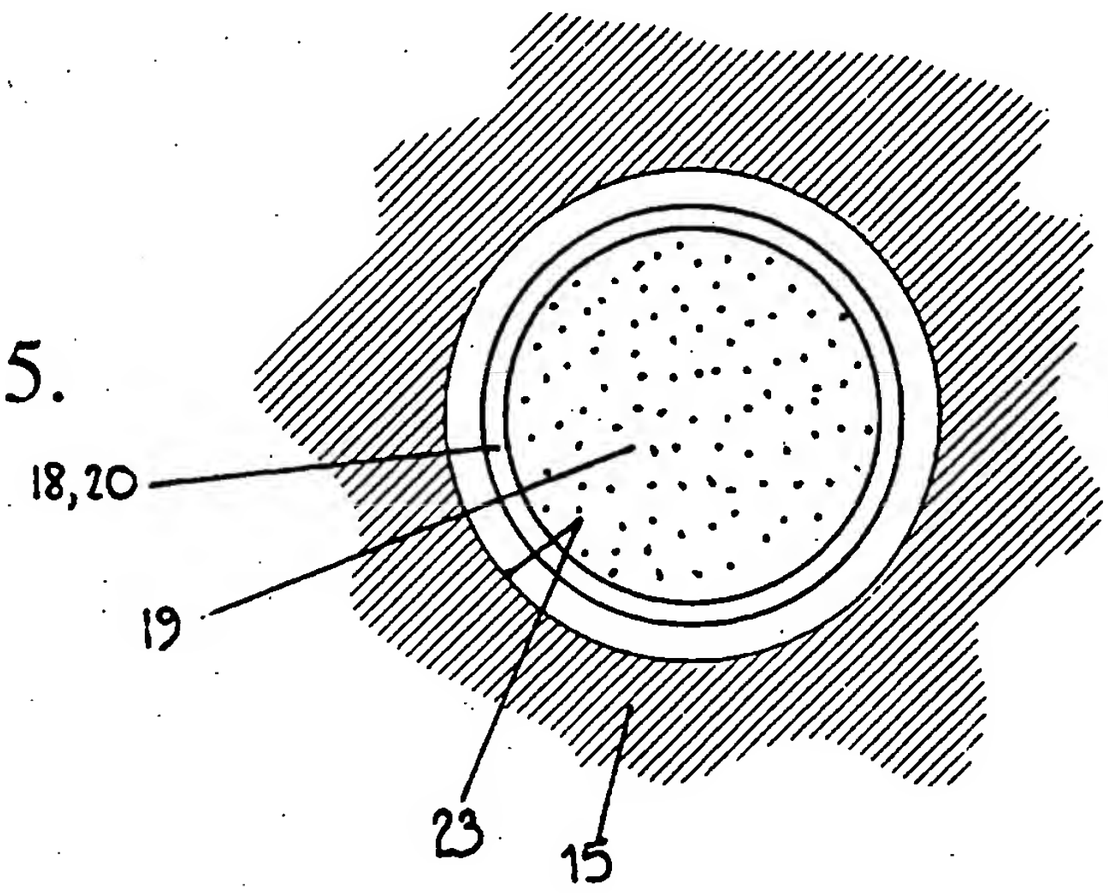
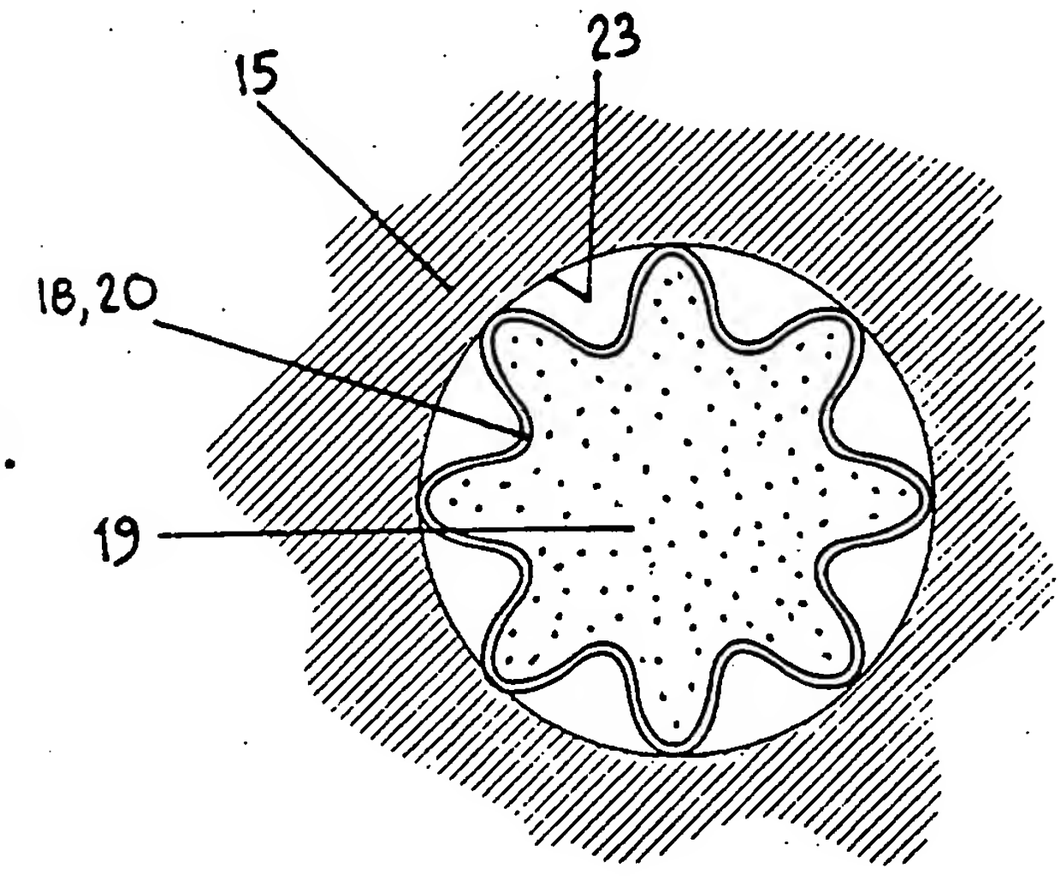


Fig 6.



INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00060

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: B22D 19/14, 1/00 // B22D 17/02, C22C 1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : B22D 19/14, 1/00, 17/02, C22C 1/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT: WPAT, JAPIO (1) B22D 19/14
(2) B22D 1/00, 17/-, 19/-, C22C 1/10 with keywords filler: or partic: or powder:

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Patent Abstracts of Japan, C-382, page 157, JP 61-133336 A (NIPPON LIGHT METAL CO LTD) 20 June 1986 Abstract; figure Abstract; figure	1-4, 8-23, 25-28 5-7, 24, 29-30
X	US 4088475 A (TYLER et al) 09 May 1978 Abstract; column 1, line 61 - column 2, line 7; column 2, lines 13-27; claim 1	1-3, 8-12, 14-23
Y	US 4888054 A (POND, S.R.) 19 December 1989 Column 1, line 51 - column 2, line 8; column 3, lines 57-62	5-7, 24, 29-30

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 March 1996	27 MARCH 1996
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	Authorized officer **RAJEEV DESHMUKH** Telephone No.: (06) 283 2145

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00060

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 84-299805/48, class P53, SU 1085669 A (MURMANSK NAVAL ENG) 15 April 1984 Abstract	1, 14